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GETTING TO KNOW THE CATACLYSMIC VARIABLE BENEATH THE NOVA ERUPTION

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Abstract. The eruption of a (classical) nova is widely accepted to be a recurrent event in the lifetime of a cataclysmic binary star. In-between eruptions the system should therefore behave as a "normal" cataclysmic variable (CV), i.e. according to its characteristic properties like the mass-transfer rate or the strength of the magnetic field of the white dwarf. How important are these characteristics for the nova eruption itself, i.e. which type of systems preferably undergo a nova eruption? This question could in principle be addressed by comparing the post-nova systems with the general CV population. However, information on post-novae is scarce, even to the extent that the identification of the post-nova is ambiguous in most cases. In this paper we inform on the progress of a project that has been undertaken to significantly improve the number of confirmed post-novae, thus ultimately providing the means for a better understanding of these objects.

Key words: binaries: close – novae, cataclysmic variables – stars: variables: general

1. Introduction

A nova eruption in a cataclysmic variable (CV) occurs as a thermonuclear explosion on the surface of the white dwarf primary star once it has accumulated a critical mass from its late-type, usually main-sequence, companion. In the process material is ejected into the interstellar medium, typically amounting to 10^{-5} to 10^{-4} $M_\odot$ yr^{-1} (e.g., Yaron *et al.*, 2005). Since the system is not destroyed by the eruption, this is thought to be a recurrent event, with recurrence times $> 10^3$ yr (see Shara *et al.*, 2012a).

In-between nova eruptions the binary is supposed to appear as a "normal" CV, i.e. its behaviour is dominated by its current mass-transfer rate and the magnetic field strength of the white dwarf (Vogt, 1989). Furthermore, the hibernation model predicts that most of the time between erup-

tions the system passes as a detached binary (Shara *et al.*, 1986; Prialnik and Shara, 1986). While there is still no observational evidence for this scenario, i.e. the state of actual "hibernation" (e.g., Naylor *et al.*, 1992), it is already well established that old novae are part of the CV community. For example, the system DQ Her (Nova Her 1934) is known as the prototype intermediate polar, while RR Pic (Nova Pic 1925) shows the characteristics of an SW Sex CV (Schmidtobreick *et al.*, 2003a). Especially important in this context has been the discovery of nova shells around the dwarf novae Z Cam and AT Cnc (Shara *et al.*, 2007, 2012b), since it proves that (at least some) original CVs are also old novae.

All in all, however, our knowledge on old novae is largely incomplete. There are about 200 reported nova eruptions that occurred before 1980 (Downes *et al.*, 2005), but for less than half of them a spectrum of the post-nova has been obtained, and about 80 objects even still lack an unambiguous identification. A first attempt to remedy this situation was undertaken by Schmidtobreick *et al.* (2005) who, however, concentrated exclusively novae with large eruption amplitudes. Among others, they recovered the old nova V840 Oph, an apparently carbon-rich CV (Schmidtobreick *et al.*, 2003b) which raises the question if the abundance pattern of novae is different from other CVs.

Furthermore, only for 28 pre-1980 novae the orbital period is well established. Because the period distribution diagram is one of the most important tools in the study of the evolution of compact binaries, this scarcity of respective information presents a severe obstacle for any systematic study on old novae and their place within the general CV population. This concerns questions like the importance of magnetic fields for the nova eruption (what is the fraction of magnetic CVs among novae compared to the general CV population?), the mass-transfer rate averaged over long time-scales (is there a bias against intrinsically faint systems?), and the hibernation model (do post-novae eventually become detached?).

2. The search for old novae

In order to establish a sample of properly identified post-novae we have begun observations of the nova candidates listed in the Downes *et al.* (2005) catalogue. We limit our research to novae that were reported to have erupted at least 30 years ago (i.e. before 1980) because in most systems the con-

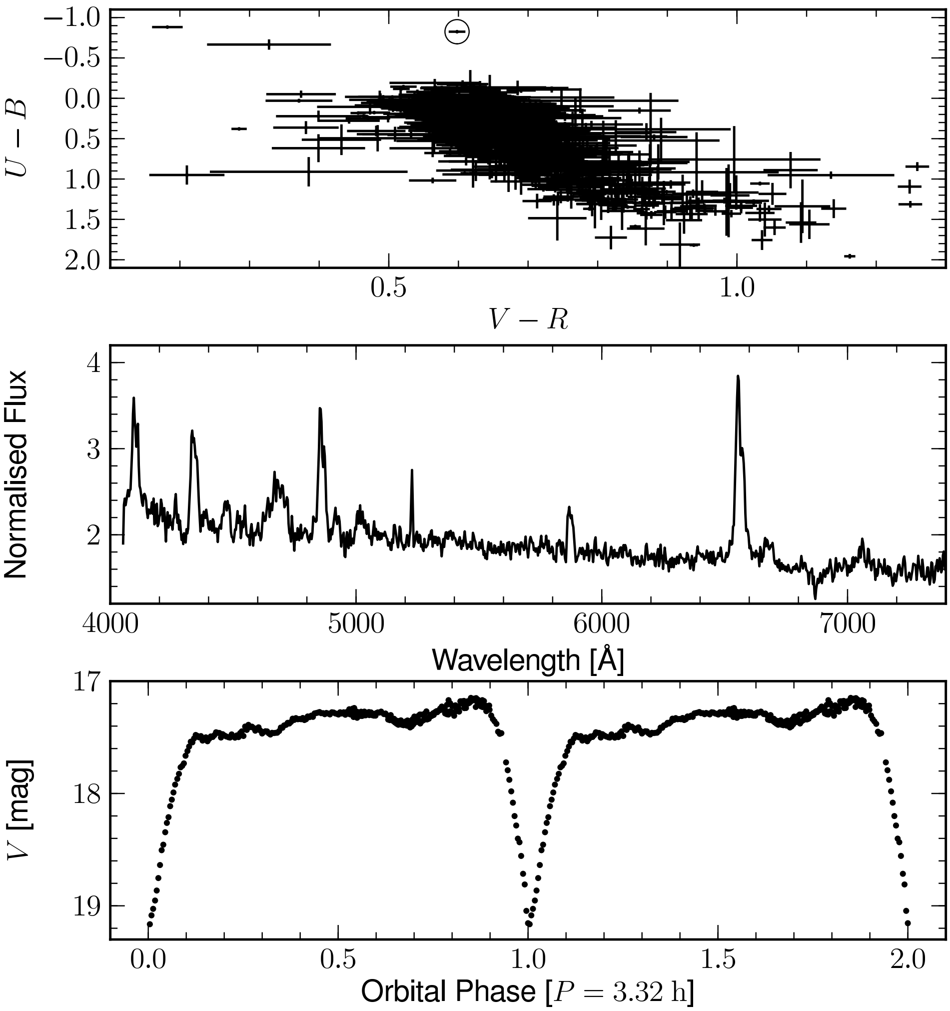

Figure 1: The data on the old nova V728 Sco, taken in three runs using EFOSC2 (Eckert, Hofstadt and Melnick, 1989) on the ESO-NTT, La Silla, Chile. **Top:** Colour-colour diagram of the $4.5' \times 4.5'$ field centred on coordinates taken from the Downes *et al.* (2005) catalogue. The nova is marked by a circle. **Middle:** Low-resolution spectrum that confirmed the nova candidate. **Bottom:** Photometric light curve folded on the orbital period of 3.32 h.

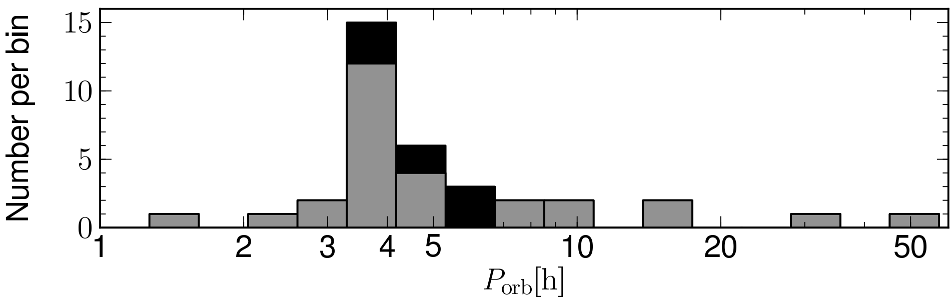

Figure 2: The period distribution of the pre-1980 novae. New systems are shown in black.

tribution of the nova shell in the optical range becomes negligible after about three decades. First results of this survey have been published in Tappert *et al.* (2012).

We use UBVR photometry to select candidates for the post-nova based on their position in the colour-colour diagram. The typical components of CVs (white dwarf + red dwarf + accretion disc or stream) place these systems away from the main-sequence, the actual position depending strongly on the relation between the individual contributions. The candidates are then examined with long-slit spectroscopy for CV characteristic features, like emission lines of the hydrogen and helium series. Finally for the brightest confirmed post-novae we attempt to derive the orbital period via time-series spectroscopy or photometric light curves.

In Fig. 1 we present our study on the old nova V728 Sco as an example. The system erupted in October 1862 (Tebbutt, 1878), putting it among the five oldest novae in the southern hemisphere. Our UBVR diagram (top plot) shows the nova well separated from the main-sequence. The long-slit spectrum presents for a nova unusually strong emission lines of the Balmer and HeI series, indicating a comparatively low mass-transfer rate. The presence of HeII λ4686 emission, on the other hand, is evidence for a hot component somewhere in the system. The width especially of the low-excitation lines indicates a high system inclination. The latter is confirmed by our time-series photometry (bottom plot) that reveals an eclipsing system with an orbital period of 3.32 h.

3. The story so far

The initial sample of reported pre-1980 nova eruptions in the southern hemisphere (DEC $< +20$) consisted of 28 novae with known orbital period, 9 confirmed novae with unknown period, 32 targets without a post-nova spectrum, and 86 objects with no proper identification. In the course of our project we have since then confirmed 13 novae spectroscopically and identified two variable stars (potentially Miras) whose variability had been mistaken for a nova eruption (Tappert *et al.*, 2012, give details on the majority of these results). We have furthermore determined the orbital period for eight novae, which already represents an increase of almost 30% with respect to the previously known periods. Among those eight there are two eclipsing novae: V728 Sco, with $P_{\rm orb} = 3.32$ h, and V909 Sgr, with $P_{\rm orb} = 3.44$ h. Note that the latter object had already been reported by Diaz and Bruch (1997) to be an eclipsing nova with a possible period of 3.36 h.

In Fig. 2 we show the period distribution of our sample. The eight additions of our present research further emphasise the apparent clustering of the orbital periods around 3–6 h, with 2/3 of the novae having periods in this range. This is the region where the CVs with the highest mass-transfer rates are situated (Townsley and Gänsicke, 2009). This clustering is therefore not unexpected since it appears to support the simple idea that the white dwarfs in CVs with high mass-transfer rates accumulate the critical mass for a nova eruption faster, leading to shorter eruption recurrence times than for low-mass-transfer CVs. However, the current sample size of 36 novae is much too small for definite conclusions.

Our project still very much represents work in progress. New observations are already underway, with more planned for the future. We therefore expect to significantly improve on the nova sample in the next years, so that it can be used for in-depth statistical analyses.

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